

Spatial quantification of community resilience in contexts where quantitative data are scarce: The case of Muzarabani district in Zimbabwe

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There has been an upsurge in tools for measuring resilience of the past decade. Despite this progress, we argue, there are few studies focusing on the spatial quantification of resilience in the context of multiple hazards, particularly in developing countries. Placing a particular emphasis on the contribution of geography to resilience studies, this paper examines the spatial variation of community resilience to disasters in Muzarabani, Zimbabwe. Place-specific resilience variables are selected from the 2012 national census report to develop a disaster resilience index for Muzarabani district. A principal component analysis technique was used to analyse the overall and subcomponents of resilience to identify wards that needed policy intervention. Using the Geographical Information Systems tool to model the spatial variation of community resilience and its subcomponents, we found a geographic variation in community resilience across Muzarabani district, with the majority of the wards scoring low to below low levels of overall resilience. Although we view this study as being complementary to qualitative studies, it would appear quantifying and visualising resilience provide possible explanations and actions required for decision-makers to address the resilience gaps and disaster risk reduction broadly.

KEYWORDS

disaster resilience, geographical information systems, principal component analysis, resilience geographies, resilience variables, Zimbabwe

1 | INTRODUCTION

Broadly likened to the antibiotic that acts against a wide range of disease-causing bacteria, resilience is not only designated as the capacity to cope with change and uncertainty, but also as a bridging concept across academic disciplines and the development–humanitarian divide. In fact, from the multiplicity of its definitions, all sorts of activities can be justified under the resilience umbrella. However, it is our contention that a minimum consensus on its constitutive features has been reached, with a significant contribution from geography scholars (Alexander, 2013; Davoudi & Porter, 2012; Gallopín, 2006; Manyena, 2006; Pelling & Manuel-Navarrete, 2011; Weichselgartner & Kelman, 2014a). Based on its growing influence, resilience is an overarching concept for guiding disaster risk reduction, climate change adaptation and sustainable

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development policies and practices (Sharifi & Yamagata, 2016). Despite this progress, we argue, there are few studies that suggest how to spatially quantify resilience in the context of multiple hazards, particularly in developing countries.

Using principal component analysis (PCA) and the geographical information system (GIS) tools, this paper presents a spatial quantification of community resilience to disasters in Muzarabani district, Zimbabwe. A spatial quantification of resilience is timely. Resilience mapping can serve as an early warning tool as well as inform interventions prior to the occurrence of destabilising events in order to save lives and livelihoods. Although there are several disciplines such as ecology, psychology, engineering and geography implicated in the conceptualisation, the intention here is not to comprehensively engage into the resilience debate, which has been extensively dealt with by several scholars (Adger et al., 2005; Alexander, 2013; Folke, 2005; Manyena, 2006; Sherrieb et al., 2010; Weichselgartner & Kelman, 2014b; Welsh, 2014). This includes avoiding the debate on what Matyas and Pelling (2012) refer to as resolved and unresolved issues of resilience. The resolved issues according to Matyas and Pelling (2015), cited by Manyena (2016, p. 43), include:

1. vulnerability and resilience are not simply opposites: there is some overlap between them;
2. resilience is more process oriented than outcome oriented; and
3. resilience is more than just bounce-back; it is not possible to bounce back to the same position before the disaster as individuals and organisations within structures undergo change.

Although we do not debate the unresolved issues such as whether resilience is a spontaneous or a deliberate process, and the interactions that cause it, we do highlight the importance of transformative resilience, which implicates the role of power, politics and cultural values. We particularly examine the critical research gaps, the variables that are used to construct the resilience indexes and reiterate the need to select variables that are context specific, as there is “no one-size-fits-all resilience measure, nor should there be” (Keating et al., 2017, p. 3). The discussion critically examines the spatial variation of community resilience across 29 wards of Muzarabani, highlighting the implications of levels of resilience and the possible explanations and actions required to address the resilience gaps.

1.1 | Defining resilience perspectives

Although resilience is now a ubiquitous concept in many science and policy circles, it is a polysemic concept that has been defined differently in different disciplines and contexts (Sharifi & Yamagata, 2016). Derived from the Latin word *resilio* meaning to jump back (Lei et al., 2014), there is now a diversity of resilience definitions. Many definitions in Table 1 are similar, but with notable overlaps with a number of concepts used across disciplines, such as ecology, socio-ecological systems (SESs), engineering, disaster risk reduction, climate change, economics and so on (Skerratt, 2013; Wilson, 2013).

Among the most influential perspective on resilience is Holling's (1973) definition in relation to ecological systems. Holling (1973) viewed resilience as a measure of the persistence of the systems and their ability to absorb change and disturbance while maintaining the same relationships between state variables. This view is the “bounce-back” of ecological systems. Janssen et al. (2006) equate such resilience with absorbing stress, absorptive and recuperative power, perseverance and stability. However, the “bounce-back” analogy tends to be associated with the engineering resilience where resilience is understood as resistance of a system to disturbance and the speed by which the system returns to equilibrium (Manyena, 2006; Mumby et al., 2014). The engineering resilience omits multiple equilibria that may help in understanding resilience of social systems. It also assumes that a variable can return to a particular equilibrium, yet this is problematic in social systems because of their dynamic nature.

Adger (2006) explored the concept of resilience from its original use in ecology in order to examine its applicability to social systems. He defined social resilience as the ability of societies to withstand external shocks to their social infrastructure. This definition is particularly resonant for resource-based communities subject to environmental stresses and shocks, and socio-political and economic upheavals. It seeks to understand the dynamic, cross-scale interactions of the coupled human environment systems (Skerratt, 2013) at every phase of adaptive cycle: growth, conservation, and collapse and reorganisation. To capture change, Westley (2002) considers the collapse and reorganisation phases as feedback loops to systems under severe perturbations. Such systems can descend into permanent dysfunction, bounce back in the same domain or create new structures and identities.

Although the SES conception of resilience is descriptive, it offers considerable scope for enhanced policy through themes such as scale, functional persistence, self-organisation and social learning. These themes contribute to our understanding of resilience in many ways. The SES view emphasises the importance of scale in understanding resilience. Resilience can be at individual, community, national level and beyond. The SES resilience acknowledges disparities at these

TABLE 1 Some of the resilience definitions

Author	Context	Definition
Bodin and Wiman (2004)	Physical systems	The speed at which a system returns to equilibrium after displacement, irrespective of oscillations, indicates the elasticity (resilience)
Holling (1973)	Ecological systems	The measure of the persistence of systems and of the ability to absorb change and disturbance and still maintain the same relationships between state variables
Walker et al. (2004)	Ecological systems	The capacity of a system to absorb a disturbance and reorganise while undergoing change while retaining the same function, structure, identity and feedback
Gunderson (2000)	Ecological systems	The magnitude of disturbance that a system can absorb before its structure is redefined by changing the variables and processes that control behavior
Tilman and Downing (1994)	Ecological systems	The speed at which a system returns to a single equilibrium point following a disruption
Walker et al. (2002)	Socio-ecological systems	The ability to maintain the functionality of a system when it is perturbed or the ability to maintain the elements required to renew or reorganise if a disturbance alters the structure of function of a system
Carpenter et al. (2001)	Socio-ecological systems	The magnitude of disturbance that a system can tolerate before it transitions into a different state that is controlled by a different set of processes
Luthans et al. (2006)	Psychology	The developable capacity to rebound from adversity
Bruneau et al. (2003)	Geography; disaster risk reduction	The ability of social units to mitigate hazards, contain the effects of disasters when they occur and carry out recovery activities that minimise social disruption and mitigate the effects of future earthquakes
Paton et al. (2000)	Disaster management	Resilience describes an active process of self-righting, learned resourcefulness and growth. The concept relates to the ability to function at a higher level psychologically given an individual's capabilities and previous experience
Coutu (2002)	Individual	Resilient individuals possess three common characteristics. These include an acceptance of reality, a strong belief that life is meaningful and the ability to improvise
Hamel and Valikangas (2003)	Organisational systems	Resilience refers to the capacity for continuous reconstruction
Horne and Orr (1998)	Organisational systems	Resilience is the fundamental quality to respond productively to significant change that disrupts the expected pattern of an event without introducing an extended period of regressive behaviour
McDonald (2006)	Organisational systems	Resilience conveys the properties of being able to adapt to the requirements of the environment and being able to manage the environment's variability
Hollnagel et al. (2006)	Engineering	The ability to sense, recognise, adapt and absorb variations, changes, disturbances, disruptions and surprises
Grotberg (1996)	Psychology	A universal capacity which allows a person, group or community to prevent, minimise or overcome the damaging effects of adversity
Wildavsky (1989)	Organisational systems	An organisation's ability to adjust to harmful influences rather than to shun or resist them
Woods (2015)	Engineering systems	Resilience has four basic concepts: (1) resilience as rebound from trauma and return to equilibrium; (2) resilience as a synonym for robustness; (3) resilience as the opposite of brittleness, i.e., as graceful extensibility when surprise challenges boundaries; (4) resilience as network architectures that can sustain the ability to adapt to future surprises as conditions evolve
Mallak (1998)	Individual/organisational	Resilience is the ability of an individual or organisation to expeditiously design and implement positive adaptive behaviours matched to the immediate situation, while enduring minimal stress
United Nations International Strategy for Disaster Reduction (UNISDR) (2005)	Geography; disaster risk reduction	The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure. This is determined by the degree to which the social system is capable of organising itself to increase this capacity for learning from past disasters for better future protection and to improve risk reduction measures

(Continues)

TABLE 1 (Continued)

Author	Context	Definition
Manyena (2006)	Geography; disaster risk reduction	The intrinsic capacity of a system, community or society predisposed to a shock or stress to adapt and survive by changing its non-essential attributes and rebuilding itself

scales, the impact and direction of interaction between scales and the role of feedbacks at different scales. Functional persistence is an outcome in the conception of SES resilience, while self-organisation and social learning are both processes that can lead to resilience. The latter form a focal point in contemporary resilience (Matyas & Pelling, 2012). Despite providing a holistic interpretation of resilience, SES resilience neither accounts for political systems nor considers the role of agency in resilience building. Moreover, its application has not yet engaged with opportunities for development that may arise when the resilience systems collapse (Brown & Westaway, 2011).

For environmental geographers, ecological origins are more likely to have influenced the disaster resilience perspective. The term resilience refers to the capacity of a social system potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure (UNISDR, 2009). The disaster resilience, as it has come to be referred, is determined by the degree to which the social system is capable of organising itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures. Among the criticisms of resilience, particularly from human geography, for example Manyena et al. (2011), is the bounce-back notion of resilience associated with engineering, which suggests a return to the status quo that may have caused the disaster in the first place, if not create an “accelerated status quo” (Pelling & Dill, 2009). The “bounce-back” notion can make communities worse off than before the disaster, including descending into permanent dysfunction. The other danger with the “bounce-back” notion of resilience is the possibility of a return to the hazard paradigm where hazards were disasters per se. Yet, the hazard paradigm was rejected following demonstrations that disasters had varying impacts on different social groups (Grove, 2013). O’Keefe et al. (1976) proposed a paradigm shift from hazard to human vulnerability. While the vulnerability paradigm recognises that a disaster event is characterised by change, the “bounce-back” notion appears to ignore the transformative capacity of disasters. In contrast, the “bounce-forward” notion of resilience has been proposed to recognise that the disaster event brings about change, including collapse, decay, chaos, loss of structure, uncertainty and loss of connectedness (Manyena et al., 2011). The bounce-forward notion of resilience advances the notion of transition and transformation consistent with the adaptive cycle’s collapse and reorganisation phase.

The “bounce-back” versus the “bounce-forward” ability is a way of thinking about resilience. In his contribution to the 2016 World Disaster Report (IFRC 2016), Manyena asserts that a focus on the bounce-forward ability represents a shift from a reactive to a proactive transformational agenda that goes beyond recovery from disasters. He further illustrates the bouncing-back and the bouncing-forward pathways of resilience building along a time scale (Figure 1). The “bounce-back” view of resilience, he argues, assumes a return to the “normal” situation *before* the disaster event. Along this line of thinking, a return to the pre-existing conditions does not bring any positive change to affected population groups. Instead, the affected groups may become worse off than before when disasters reduce their capacities. On the contrary, the “bounce-forward” view of resilience recognises that, as disasters are accompanied by change, a disaster event creates new opportunities and possibilities to transform the socio-economic conditions through novelty, experimentation and invention, with the potential of transforming the status quo.

Notions of transformative resilience, in which communities can make, remake and unmake social structures, has been associated with community organisation, signifying the potential of community agency and radicalised approaches to deal with destabilising events (Manyena, 2014). Community organisation has been linked to social capital, an extension of Bourdieu’s (1984, 1987) work on “capitals,” suggesting resilience should go beyond material outcomes, which are of neoliberal concern, to include processes that recognise the differentiated inner capabilities of an individual or society to choose (Nussbaum, 2011; Sen, 2009). Drawing on Putnam’s (2000) work, Aldrich (2012) demonstrates how social capital networks, norms, cooperation and trust serve as informal insurance and mutual assistance for disaster survivors. That social capital takes the forms of “bonding” (where social network benefits are distributed within communities) and “bridging” (where social networks contribute to cross-cultural and intergroup linkages) has been extensively discussed in the literature (Aldrich, 2012; Ferlander, 2007; Paxton, 2002; Putnam, 1993). Bonding capital can take many forms, such as a high level of participation of local communities in community meetings, membership in self-help community groups and community-based organisations. There is need, however, to recognise that localised social networks can be closed to outsiders, thereby contributing to more dangerous forms of exclusionary and competitive politics at the macro level (Coffé & Geys, 2007).

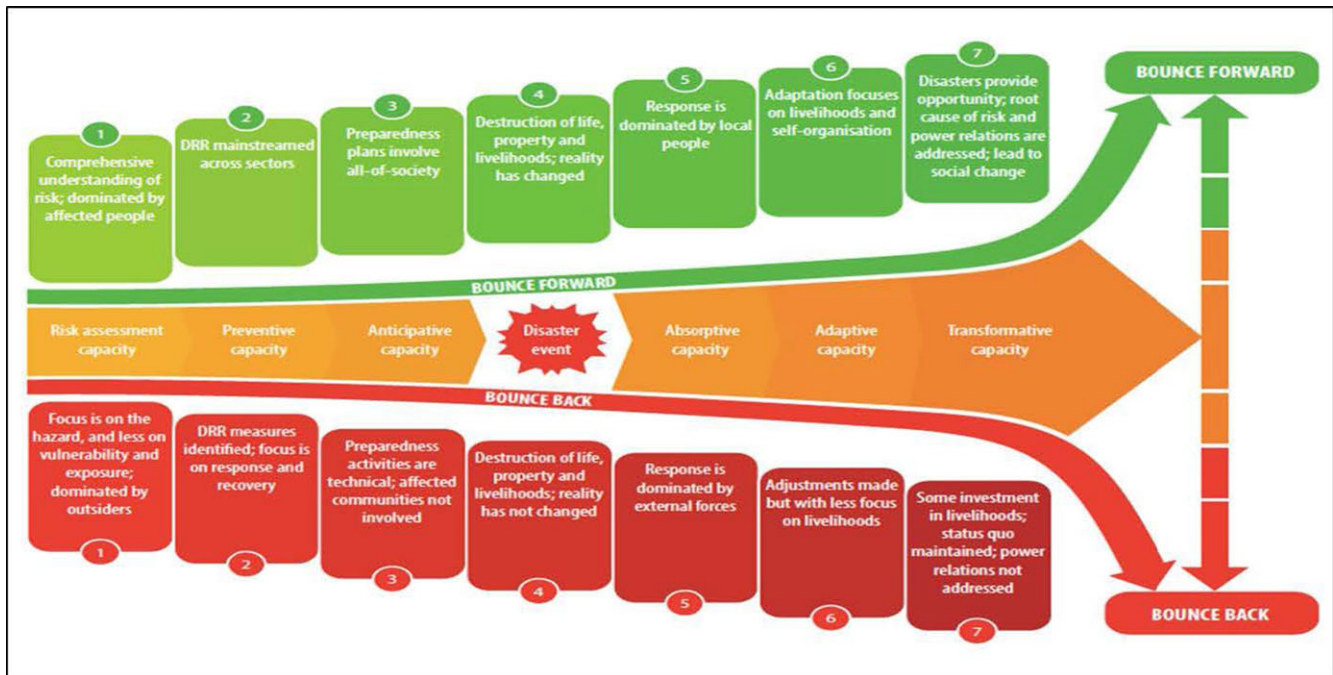


FIGURE 1 Bouncing-back and bouncing-forward resilience pathways (Source: Manyena; IFRC, 2016).

If community resilience is understood as a measure of adaptive (Norris et al., 2008), absorptive and transformative capacities (Constas et al., 2014), the indicators are likely to help profile the levels of resilience, and how economic development, social capital, community competence and information and technology interact to form community resilience to disasters. Figure 1 highlights three interrelated elements of resilience. First, understanding the nature and relationships of risk drivers (hazards, vulnerability and exposure) to produce a disaster is not an end in itself; it should involve the types and levels of capacities needed to deal with the risks. These capacities mainly fall into five categories (preventive, anticipative, absorptive, adaptive and transformative) that are not necessarily linear but tend to occur simultaneously. To be sure, as prevention and mitigation may not eliminate all the risks, this requires anticipative capacity for the community system to absorb the impact. In addition to the preventive, anticipative, absorptive and adaptive actions, which, at best, reproduce, maintain or accelerate the status quo, the transformative capacity is required, for affected communities to create a new system when the old one becomes untenable. Finally, there are two resilience outcomes, with the bouncing-forward actions resulting in social transformation to address the root causes of disasters while the bouncing-back view may result in transient collapse, or permanent dysfunction with significant levels of vulnerability. The spatial quantification of resilience offered by geographers provides a conceptual and visual tool for operationalising the resilience into policy and programmes.

1.2 | Measuring resilience to disasters

There has been an upsurge in tools for measuring resilience over the past decade. Using search words such as “measuring resilience tool,” “measuring resilience framework,” “resilience assessment,” “resilience modelling disasters” and “resilience index” from the Web of Knowledge, Google scholar, a general Google search and specific websites for governments, United Nations agencies and non-governmental organisations, 43 tools with labels such as toolkits, models, indexes, scorecards and policy guides were identified (Table 2). The tools reflect the width and breadth of resilience, and range from a focus on a single risk, through to multiple risks and other wider aspects of development, such as poverty and economic recession. Table 2 reveals at least three aspects, which resilience scholars should consider in advancing resilience measurement.

First, of the 43 community resilience tools (Table 2), about one-third (14) of these were published in refereed journals, with the rest being obtained from grey literature sources. The dominance of tools from grey literature not only suggests the urgency for practice to operationalise resilience, but also reflects a gap for scholars to produce tools that may increase both the conceptualisation and operationalisation of resilience.

Second, Table 2 also reveals that most resilience frameworks are based on the developed world, dominated by North America, particularly the United States, with only four and six specifically focused on Africa and South East Asia

TABLE 2 Resilience frameworks developed between 2000 and 2016

Element	Time				Total
	2000–2004	2005–2009	2010–2014	2015–2016	
Type of tool					
Model	2	2	5	1	10
Index		1	8	4	13
Toolkit	2	4	10	2	18
Scorecard			1		1
Policy guide			1		1
Type of risk					
Natural	2	5	9	2	18
Multiple	2	2	19	5	28
Developer					
Academic	2	2	7	3	14
Practitioner	2	5	16	4	27
Jointly academic/practitioner			3		3
Geographical focus					
Africa	1		3		4
Americas	2	3	9	2	16
South East Asia		1	4	1	6
Europe			1		1
Asia Pacific			1	2	3
Australasia			1		1
Global	1	3	7	2	13
Methodology					
Quantitative	1		6	2	9
Qualitative	2	3	8	2	15
Both quantitative and qualitative	1	4	12	3	20

Source: Authors

respectively. Paradoxically, it is in the developing world where the capacity to cope with change and uncertainty is more needed than in the developed world (Mazaris et al., 2017; O'Brien et al., 2006). We believe it is timely for geography and cognate disciplines to provide tools for assessing disaster resilience, particularly from the global South, not only to inform resilience programmes but also to broaden the conceptualisation of, and debate on, resilience geographies.

Third, methodologically, the resilience tools are informed by both quantitative and qualitative approaches, although there is a bias towards the qualitative approach. What is common within and between these quantitative and qualitative methodologies is the indicator approach. Indicators of disaster resilience are factors, which impact positively on the ability of a community or households to cope with, and adapt to the disaster (Frazier et al., 2013). These indicators consider place-specific social and biophysical variables, as opposed to national or regional factors. National or regional factors may mask local, context-specific variables that are important for assessing community resilience to disasters. Considering disaster resilience will vary across communities, and at scales that are interdependent of the national or regional scales, place-specific factors are important in resilience analysis (Frazier et al., 2013; Siebeneck et al., 2015). Many of the existing studies ignore the quantification and spatial context of resilience (Ainuddin & Routray, 2012), yet quantifying and visualising resilience at local levels can provide a platform for decision-makers to effectively allocate resources, monitor and capture components of resilience that need attention, and provide effective strategies to reduce the underlying risks to disasters.

Bruneau et al.'s (2003) systems approach helps us understand that community resilience to hazards “depends on the robustness, redundancy, resourcefulness and rapidity of the social and physical systems in place prior to the disaster” (Siebeneck et al., 2015, p. 957). Although Bruneau et al.'s (2003) framework accounts for the social, economic, technical,

and organisational characteristics of the community, because these characteristics are multiple, they cannot be captured by a single indicator. Several, and in some cases, proxy indicators are needed. While Cutter et al.'s (2008) disaster resilience of place (DROP) model includes economic, social, ecological, institutional and physical capitals, quantifying the variables of the DROP model at the local level is a challenge due to limited data availability in most developing countries. Similarly, while Mayunga's (2007) capital-based framework (CBF), which includes social, economic, human, natural and physical capitals, may provide metrics in which the spatial patterns of resilience can be visually represented, the absence of the political capital, which can be traced to the sustainable livelihoods framework, depoliticises resilience.

The downside of the indicator approach is that it tends to decontextualise and depoliticise resilience, making it difficult to recognise relevant contributing factors and to gain full understanding of how hazards and vulnerabilities shape resilience outcomes (Weichselgartner & Kelman, 2014a, 2014b). However, if the quantitative approaches are developed alongside qualitative methodologies, and if appropriately co-developed by affected communities, scientists and decision-makers, the indicator approach may form the basis for communities to advocate for structural changes that underlie their vulnerabilities, particularly at the local scale where resilience analyses are needed (Weichselgartner & Kelman, 2014a, 2014b). Table 3 shows selected resilience indicators found in the literature. These indicators can be categorised into livelihood capitals that enhance (+) or decrease (–) community resilience to disasters. For example, the percentage of the population earning above the subsistence wage can increase resilience of a household by creating disposable income that enables the household to recover quickly from disaster events (Cutter et al., 2010). The availability of social networks, trust and norms can enable community members to share resources such as draught power that is critical in rural areas of developing countries (Cramb et al., 2004).

2 | STUDY SITE, DESIGN AND METHODS

2.1 | Study site

The study was located in Muzarabani district, situated about 250 km north of Harare, Zimbabwe's capital city (Figure 2). In 2012, Muzarabani had a population of approximately 123,000, distributed over 29 wards and about 27,000 households, averaging 4.5 persons (ZimStat, 2012). About 97% of the Muzarabani population live in rural areas (ZimStat, 2012) and these people mainly depend on small-holder rain-fed agriculture; they grow maize, small grains, cotton and tobacco. The crop productivity is very low due to recurrent droughts and poor soils (Mavhura et al., 2015).

TABLE 3 Selected resilience indicators to hazards

Indicator	Variable(s)	Effect on resilience (increases [+] or decreases [–])
Education	Number of years of education attainment of population aged 15 and above	(+)
Age	Percent of elderly population	(+)/(–)
Gender	Percent of female-headed households	(–)
Social networks, trust	Availability of social networks, trust and norms	(+)
Poverty	Percentage of households in poverty	(–)
Employment	Percentage of population employed	(+)
	Percentage of population not entirely dependent on single sector	(+)/(–)
Family income	Percentage of population earning above subsistence wage	(+)
Household materials	Percentage of households of permanent materials	(+)/(–)
Energy	Percentage of households with access to electricity/gas	(+)
Water	Percentage of population with access to safe drinking water	(+)
Sanitation	Percentage of households with access to proper sanitation	(+)
Physicians ratio	Number of physicians per 10,000 people	(+)
Hospital beds	Number of hospital beds per 10,000 people	(+)
Transportation	Number of roads per square km	(+)

Source: Ainuddin and Routray (2012); Cutter et al. (2008, 2010); Mayunga (2007); Norris et al. (2008); Siebeneck et al. (2015)

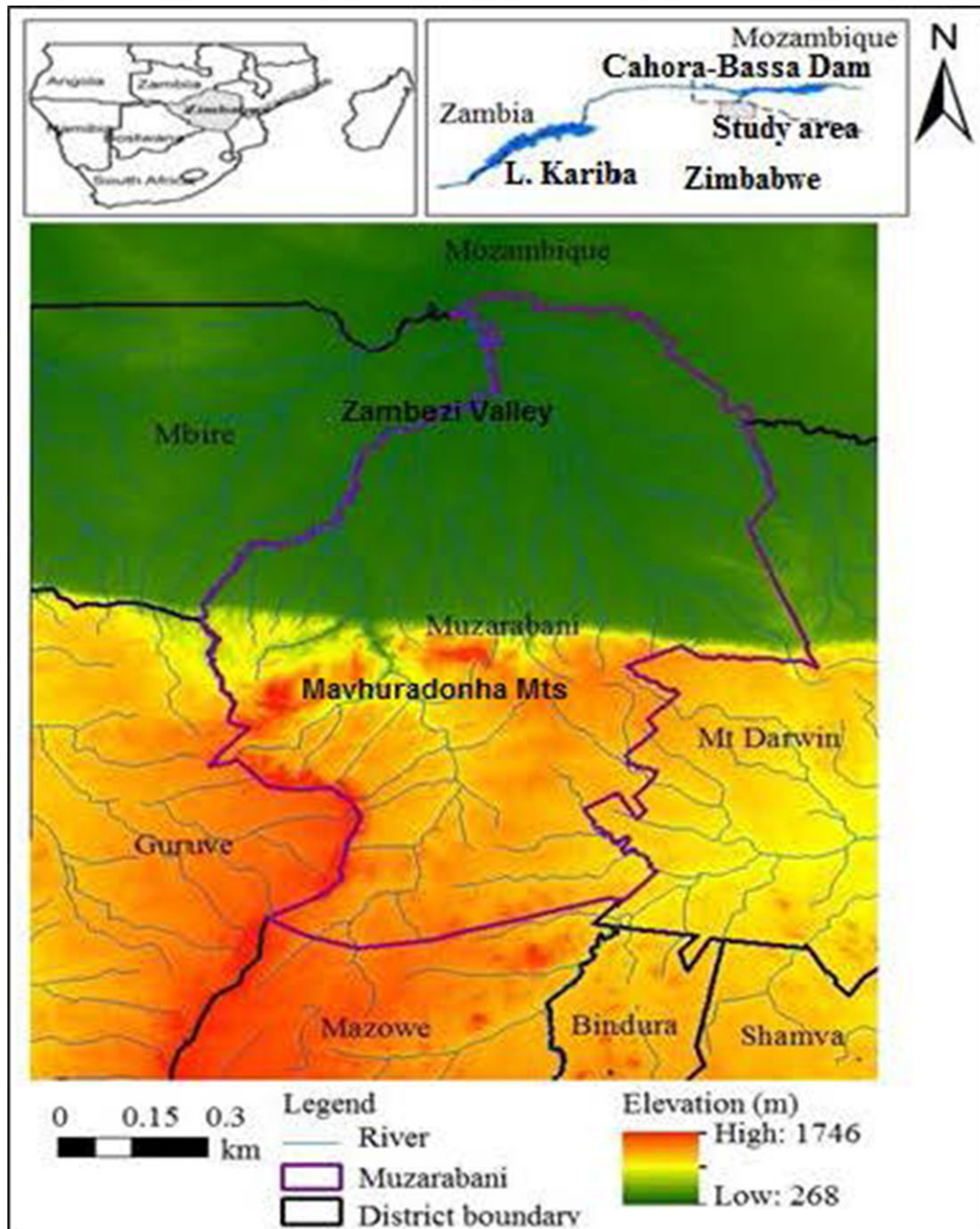


FIGURE 2 Location of study area: Muzarabani.

As the term Muzarabani means a plain inundated with water, in the local Shona dialect, Muzarabani is at high risk of flooding. Although the floods are seasonal, occurring between January and February, when the rainfall season is at its peak (Mavhura et al., 2013) it is exacerbated by the human engineered context. Being located downstream of Lake Kariba, but upstream of the Cahora-Basa Dam in Mozambique, Muzarabani is susceptible to flooding (Mavhura et al., 2013). When the water level in Lake Kariba rises above thresholds, it is released to avoid dam failure, often at the peak of the rainfall season, resulting in a substantial increase in the discharge of the Zambezi River. Further downstream, if Cahora-Basa Dam levels continue to rise due to inflows from the tributaries of the Zambezi River and releases from Kariba Dam, backflow flooding in Muzarabani may occur, particularly when the opening of floodgates at both Cahora-Basa Dam and Lake Kariba are not well coordinated, or if the releases at Cahora-Basa are exceeded by the inflows from the Zambezi River systems. In addition, during the summer season, intense rainfall is sometimes experienced, resulting in flash flooding and severe land degradation (Mudavanhu et al., 2015). Tropical cyclones also bring floods that damage dwellings, critical infrastructure and

livelihoods, and disrupt basic services. The floods in Muzarabani cause secondary hazards, mainly water-borne diseases such as malaria, diarrhoea, typhoid and cholera (Mavhura et al., 2017).

Muzarabani district is characterised by communal and large-scale commercial farmland. It includes the Mavuradona Wilderness Area, a formally protected wildlife area, which covers 650 km² of the escarpment mountains. To the south, the district is bordered by commercial farms on the highveld. To the east and west, it is bordered by communal farms in the mountains, while to the north it is bordered by communal farms in the Zambezi Valley. Crop cultivation is practiced mainly along water courses and in areas with fertile soils, for example, where there is a flat terrain with deeper soils. Most farming is small-scale dry-land cultivation and the main wet season (November–April) crops include maize and cotton. To supplement their wet season harvests, assorted vegetables and maize are planted in small-scale bucket-irrigated gardens along the rivers during the dry season (May–October).

The resilience or lack of it in Muzarabani district should be contextualised to Zimbabwe's socio-economic vulnerability to disasters. Zimbabwe is one of the poorest countries in the world and ranks 154 out of 188 countries in the human development index (UNDP, 2017). In 2016, the life expectancy stood at 59.2, with about one in five of the population surviving on less than US\$1.90 a day (UNDP, 2017). It is estimated that about 1.3 million of the population are living with HIV and AIDS (UNAIDS, 2017). The socio-economic decline experienced for more than two decades saw unemployment rates at more than 80% and dwindling support for crucial social services such as health and education. As a result, between late 2008 and mid-2009, there were 98,591 and 4,288 preventable cholera cases and deaths respectively in Zimbabwe.

Zimbabwe's lack of resilience to disasters, such as drought, is not blamed on the natural hazards, but on the bad governance by the Zimbabwe African National Union-Patriotic Front (ZANU-PF) Party (Hammar, 2008). By the 1990s the economy had declined mainly as a result of a litany of problems, including the country's unbudgeted engagement in the civil war of the Democratic Republic of Congo; a chaotic economic structural adjustment programme; hefty salaries that were paid to the liberation war veterans outside the budget lines; and siphoning of resources by senior politicians within the ZANU-PF Party.

The formation of the Movement for Democratic Change (MDC) Party in 1999, later to become the strongest opposition to ZANU-PF, was a response to Zimbabwe's economic hardships. By the 2000s, according to Bratton and Masunungure (2007), ZANU-PF had exhausted its capacity for good governance, and extended its rule through fraudulent elections, economic mismanagement, and an ill-considered and chaotically implemented programme of land seizures, which turned Zimbabwe from an agricultural exporter to a needy recipient of foreign food aid. This led to Zimbabwe's international isolation from Western powers, and by 2005, the government was essentially bankrupt and desperate to gain access to dwindling supplies of foreign exchange (Bratton & Masunungure, 2007).

The temporary reprieve to the economy between 2009 and 2013, following the 2009 government of national unity that was formed following the 2008 disputed elections, was short lived because ZANU-PF regained full control of the government after its controversial victory in the 2013 national elections (Raftopoulos, 2013). Muzarabani district, despite being ZANU-PF Party's stronghold since Zimbabwe's independence from Britain in 1980, has not been spared from these socio-economic hardships.

2.2 | Data sources

The data were obtained from interviews, focus groups and census reports. Twenty-seven interviews were conducted in 2015 and 2016 to identify, confirm the accuracy of, and validate resilience indicators. The key informants were purposively selected among members of the National Civil Protection Organisation, representatives of the Muzarabani Rural District Council and civil societies, councillors, local chiefs, village heads and small-scale farmers of the district. These stakeholders were quite pragmatic about the process of selecting variables, quantifying and visualising resilience in Muzarabani. Initially the interviewees identified 22 resilience variables that are context specific to the Muzarabani community. However, only 15 of them were finally used to model disaster resilience. Section 2.3 explains that only variables that had literature support, quantitative census data at ward level and were identified by qualitative methods were employed to develop the disaster resilience index (DRI). The 15 variables include male population; economically active population already employed, population employed in non-farming activities and those not entirely dependent on farming; female labour force participation; people with at least “O” level education; population that is non-elderly/young; households with at least five members, not living in traditional dwellings and those headed by males; households with access to electricity, safe drinking water and proper sanitation; and number of physicians and hospital beds per 10,000 people. The other seven variables are the number of roads per square km; affordable transport; availability of social networks, trust and norms; livestock ownership; access to credit facilities; good health (especially people not suffering from HIV and AIDS); and arable land; these were not used in the model because they either lacked quantitative census data at ward level or were not supported by the literature.

Although Fekete (2009) argues for the validation of resilience models with new post-disaster data, this was not possible in this research owing to the absence of such data at the ward level at the time of conducting this study. However, key informants were asked to check if the DRI's results were consistent with the living conditions of the community across the district (Arma & Gavri, 2013). This process was corroborated by focus group participants who considered the key indicator they felt was the “most influential” in defining resilience. The focus group then ranked the indicators according to importance, based on their experience in resilience assessment. Availability of social capital (networks, trust and norms); economically active population already employed; people with at least “O” level education; livestock ownership; and households with at least five members were ranked the top five variables influencing disaster resilience. Two of these variables – availability of social capital and livestock ownership – could not be used in the DRI model because they both lacked quantitative census data at the ward level. However, this verification process broadly captured the DRI components for understanding the level and type of spatial resilience in Muzarabani; that is, the variation of resilience across the 29 wards.

Finally, data for the identified resilience variables came from the most recent, 2012 census report. Census data were used because (1) they included the entire population of Muzarabani; (2) they are reliably collected using standardised questionnaires by government; and (3) the PCA technique employed in data analysis needed massive data input to develop the resilience metrics. Data from the 2012 Poverty, Income Consumption, and Expenditure Survey supplemented the income variable that was missing from census reports. In this way, the number of variables used to run the PCA increased. As often community-level disaster assessments are done at the ward level (Arma & Gavri, 2013), the ward was the spatial scale of analysis adopted in this research.

2.3 | Principal component analysis

Guided by Cutter et al. (2003), the present research identified 15 variables context specific to Muzarabani. The variables were broadly categorised into economic, social and physical capitals that can be regarded as subcomponents of community resilience. Each variable had to pass three tests before its input into the PCA: (1) it should have been identified by key informants from the study area; (2) it should have been among the disaster resilience variables found in the literature; and (3) quantitative data at the ward level from the most recent census should have been available for the variable. Table 4 provides a list of the 15 variables used to develop the DRI for Muzarabani, and their descriptive statistics based on 29 cases. Variables X_1 , X_8 , X_{10} , X_{11} , X_{12} and X_{14} have high standard deviation, showing that the data were distributed over a large range of values. There were no missing values in the data set.

The major limitation of this study is that environmental, political and institutional variables were not used due to non-availability of data at the ward level from census reports. The resilience variables used in the modelling do not guarantee that other non-captured or unknown variables might not be equally important. Another limitation is that resilience metrics could not be validated with new empirical data. This is because new census data will only be available in 2022.

After variables were discussed and agreed upon, composite indices were developed to model the spatial variation of resilience. Before constructing the index, all the raw data were standardised by transforming them into comparable scales of percentages and per capita functions. This was essential to avoid problems inherent when mixing measurement units. Then the DRI was calculated by running the PCA technique in Statistical Package for Social Scientist (Version 22). The PCA condensed the original set of 15 variables into a smaller number of linear varieties. It also identified patterns in high-dimensional data and revealed the underlying principal components which best describe variations in the data that measured community resilience (Kaźmierczak & Cavan, 2011). In this way, the PCA produced a robust and consistent set of variables that can be monitored over time to enhance community resilience (Cutter et al., 2003).

Consistent with Cutter et al. (2003, p. 251) a varimax rotation was applied, as it (1) minimises the number of variables that loaded high on a single factor, (2) increases the percentage variation between each factor, and (3) simplifies the structure of underlying dimensions and yields more independence among the factors. A Kaiser criterion (eigenvalues >1) was employed for the selection of components. This method was repeated to achieve robust and stable components. Then, two statistical tests, the Kaiser–Meyer–Olkin (KMO) and Bartlett's test for sphericity were performed to check the robustness of the model. The KMO test measured the sampling adequacy and evaluated the correlations of the data. As a rule of thumb, the KMO values are supposed to be equal to or greater than 0.6 (Fekete, 2012). Bartlett's test for sphericity was conducted to test the null hypothesis that the correlation matrix was an identity matrix. This hypothesis needed rejection.

The PCA performed very well because the variables varied across the 29 wards in Muzarabani. The DRI was developed by summing up the component loadings of the extracted principal components for each ward. Guided by Cutter et al.'s (2003, p. 254) approach, we chose an additive model where we made “no a priori assumption” about the weighting of each component in the final DRI. Here, according to Cutter et al.'s (2003) approach, we assumed each component had an equal

TABLE 4 Descriptive statistics of resilience variables

Variable	<i>N</i>	Range	Min.	Max.	Mean	Std. dev.
Percentage of economically active population that is employed (X_1)	29	45.05	1.42	46.47	13.01	13.247
Percentage of population employed in non-farming (X_2)	29	26.07	0.69	26.76	7.37	7.69
Percentage of population not entirely dependent on farming (X_3)	29	26.40	0.70	27.10	7.49	7.90-
Percentage of female labour force participation (X_4)	29	10.34	0.17	10.51	2.55	2.89-
Percentage of population who attained at least 'O' level education (X_5)	29	41.92	10.90	52.82	25.19	7.77
Percentage of population that is non-elderly/young (X_6)	29	26.30	35.50	61.80	51.19	5.02-
Percentage of households with at least 5 members (X_7)	29	19.70	32.72	52.42	45.39	4.60
Percentage of households not living in traditional dwellings (X_8)	29	77.00	19.00	96.00	51.52	18.88
Percentage of households headed by males (X_9)	29	21.20	62.30	83.50	72.70	6.38
Percentage of households with access to electricity (X_{10})	29	74.00	1.00	75.00	14.83	14.19
Percentage of households with access to safe drinking water (X_{11})	29	86.00	12.00	98.00	53.00	26.17
Percentage of households with access to proper sanitation (X_{12})	29	79.00	2.00	81.00	8.52	14.37
Number of physicians per 10,000 people (X_{13})	29	3.54	0.00	3.54	0.12	0.66
Number of hospital beds per 10,000 people (X_{14})	29	236.24	0.00	236.24	11.76	43.91
Percentage of male population (X_{15})	29	5.70	47.00	52.70	49.88	1.36
Valid <i>N</i> (list-wise)	29					

N, number of cases used in the analysis; Min., minimum; Max., maximum; Std. dev., standard deviation.

Source: Authors

weighting to our understanding of spatial variability and complexity of the district's overall resilience. Following this, we classified the final resilience scores using the standard deviation, which provided a relative measure of deviation from the mean of each ward. We then analysed the subcomponents of resilience separately to identify areas that needed policy intervention. Using the ArcMap10.2 GIS tool, we created thematic maps to model the spatial variation of resilience and its sub-components, enabling us to compare the levels of resilience across Muzarabani's 29 wards.

3 | RESULTS

Commonalities from the selected variables were extracted and ranged from about 0.4 to 1,927.9. These are the proportion of each variable's variance that can be explained by the principal components. The majority of the extracted commonalities (14 out of 15) were higher than 0.5, suggesting the extracted components represented the selected variables well except one (X_{13}), whose value (0.418) was less than 0.5 ($h \geq 0.5$) (Siagian et al., 2014). After extracting the commonalities, a KMO statistical test yielded a value of 0.694, which was above the recommended minimum of 0.6 (Fekete, 2012). Bartlett's test for sphericity also indicated the correlation matrix (of items) was identical. The analysis was highly significant ($df = 105$; Sig. = 0.000).

Following the KMO test and Bartlett's test for sphericity, the PCA extracted three principal components that largely explained the total cumulative variance in resilience variables (about 90.7%) and whose factor loadings were used to develop Muzarabani's DRI (Table 5). Having conducted the PCA on the correlation matrix, we standardised the variables resulting in each variable having a variance of 1, making the total variance equal to 15, the number of variables used in this study. The first component (the highest eigenvalue) accounted for the most variance, 50.5%, and the second component accounted for as much as the left-over variance as it could, 23.6%. The variance of each successive component continued to diminish. We also used a scree plot to determine the number of components that adequately explained the correlations between the variables.

Having extracted the factor loadings of the principal components, a composite DRI score was developed (Table 6) that ranged from about -1.9 (least resilient) to about 5 (most resilient).

Considering the importance of using benchmarks for community resilience to disasters, the ArcMap10.2 GIS tool generated five categories from the final DRI scores to describe the community resilience to disasters: high; fair; low; very low; and absent. In this case, the benchmarks explained what the resilience scores mean. Table 7 describes the benchmarks for community resilience in Muzarabani while Tables 8 and 9 show the 10 most resilient and the 10 least resilient wards respectively. All wards with high resilience scores are found in Upper Muzarabani, while the majority of the least resilient

TABLE 5 Total variance explained for the resilience variables

Component	Initial eigenvalues ^a			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative % of variance
1	1,935.770	50.508	50.508	1,935.77	50.508	50.508
2	902.919	23.559	74.067	902.919	23.559	74.067
3	637.191	16.626	90.692	637.191	16.626	90.692
4	174.409	4.551	95.243			
5	108.332	2.827	98.069			
6	26.195	0.683	98.753			
7	20.867	0.544	99.297			
8	11.632	0.304	99.601			
9	7.934	0.207	99.808			
10	4.533	0.118	99.926			
11	2.206	0.058	99.984			
12	0.499	0.013	99.997			
13	0.099	0.003	99.999			
14	0.018	0.000	100.000			
15	0.005	0.000	100.000			

Extraction method: principal component analysis.

^aWhen analysing a variance matrix, the initial eigenvalues are the same across the raw and rescaled solution.

Source: Author

wards are located in the lower part of the district where the physical exposure to floods is also high. This suggests that conditions yielding low resilience in Muzarabani also promote physical vulnerability in the community. Reducing physical vulnerability conditions may enhance the resilience of the community. These wards need to be prioritised in terms of resource allocation, evacuation or policy decisions that enhance their capacities and resilience.

Using the ArcMap10.2 GIS tool, we created a map showing the overall spatial variation of resilience in Muzarabani (Figure 3a) based on the final DRI scores. The majority of wards (23 out of 29) are below the category of low resilience, suggesting most people in Muzarabani have limited access to sustainable livelihoods. The community's assets might be depleted or are ineffective to the extent that some members of the community were moving into permanent dysfunction with significant levels of vulnerability.

Based on the resilience variables used to run the PCA, we generated three more thematic maps showing three disaster resilience sub-components: economic, physical and social (Figure 3b–d). The purpose of creating the thematic maps was to conduct a comparative analysis to identify both wards and disaster resilience sub-components where policy interventions could target resilience building. The numbers inside the maps represent ward numbers.

The economic resilience scores ranged from about -0.9 to 2.6 . Seven wards (12, 13, 14, 15, 26, 28 and 29) were ranked as fair to high resilience (Figure 3b). These are all located in the upper part of Muzarabani. This shows the majority (22 out of 29) of wards' economic systems were performing poorly. People living in these wards may have relatively moderate potential to reduce disaster risk. In the event of disasters, the community's livelihoods are likely to be depleted or are ineffective, with the community descending into high levels of vulnerability. This may push the community into low well-being where it may fail to recover quickly from disasters. Interviewees confirmed that some households were disposing of their draught power (livestock) as a coping strategy. One key informant reported: "I was forced to sell two beasts so that I could purchase food which could last my family until the next (farming) season." Income from the sale of livestock is also used to purchase farming inputs that are used to enhance food security. The poor economic system may also have a negative knock-on effect on the performance of other attributes, leading to overall resilience stress. For example, one focus group stated: "Most smallholder farmers are failing to build resistant houses, invest in agriculture and send their children to schools due to high poverty levels."

The physical resilience scores fluctuated between -1.7 and 4.9 , with seven wards (6, 7, 8, 10, 15, 16 and 20) ranked as fair to high (Figure 3c). The seven wards are concentrated in peri-urban centres where housing conditions, access to electricity, water and sanitation, and medical care are improved. The infrastructure development is lagging behind in about

TABLE 6 Composite DRI scores for the 29 wards in Muzarabani

Ward name	Ward no.	Factor 1	Factor 2	Factor 3	DRI score
Chadereka	1	-0.16480	-0.73466	-0.18549	-1.08495
Maungaunga	2	-0.81383	-0.27837	-0.26230	-1.35450
Machaya	3	-0.00194	-0.87687	-0.00838	-0.88719
Dambakurima	4	-0.82107	0.80691	-0.02299	-0.03715
Kapembere	5	-0.10871	-0.94974	-0.33489	-1.39334
Gutsa	6	0.19592	-1.55233	-0.36777	-1.72418
Hwata	7	0.81465	-0.82591	-0.35690	-0.36816
Muringazuva	8	1.49187	-1.01461	-0.20846	0.26880
Chiwashira	9	-0.68007	-0.55200	-0.28347	-1.51554
Chiweshe	10	0.01571	-0.13196	5.11117	4.99492
Chinyani	11	-0.60684	1.08850	0.09793	0.57959
Botambudzi	12	0.72088	1.61385	-0.18528	2.14945
Mawari	13	0.83179	1.01834	-0.22269	1.62744
Nyamanetsa	14	-0.03423	1.18569	-0.19165	0.95981
Gatu	15	3.75539	0.16140	-0.01306	3.90373
Mukwengure	16	1.03488	-1.19621	-0.39030	-0.55163
Hoya	17	-1.09410	-0.20818	-0.09198	-1.39426
Mutemakangu	18	-1.10604	-0.13296	-0.24839	-1.48739
Utete	19	-0.39268	-0.75232	-0.30759	-1.45259
Chawarura	20	-0.37353	-1.14720	0.55784	-0.96289
Runga	21	0.19315	0.04011	-0.27310	-0.03984
Chaona	22	-0.23917	-0.14303	-0.27931	-0.66151
Kairezi	23	-1.05611	-0.55880	-0.27391	-1.88882
Chiwenga	24	-1.31169	-0.02963	-0.22776	-1.56908
Mutuwa	25	0.06075	1.11645	-0.20724	0.96996
Mutute	26	0.17119	1.85041	-0.15453	1.86707
Museredza	27	-0.00598	-0.95435	-0.33569	-1.29602
Chidikamedzi	28	0.34908	1.78345	-0.17215	1.96038
Palms	29	-0.82448	1.37403	-0.16165	0.38790

Source: Author

three quarters of the district (22 out of 29 of wards or 75.9%). Interviewees confirmed the lack of robust infrastructure like schools, roads and bridges during flooding. One elderly woman living in Chadereka Ward which experiences annual floods reported: “Emergency shelter is unavailable during floods ... The classrooms are unsafe because of the cracks caused by flood waters.” A councillor from a ward known for flooding echoed: “The road network is poorly developed and impassable during the rainy season. Some relief materials from NGOs and the government fail to reach flood victims in time due to impassable roads.” This reduces the capacity of the community to deal with flood disasters.

The social resilience scores ranged from -2.5 to 2.8. In contrast to the economic and physical subcomponents of resilience, the majority of the wards (15 out of 29 or 51.7%) have fair to high social resilience (Figure 3d). These wards include 7, 8, 11, 12, 13, 14, 15, 16, 21, 22, 23, 25, 26, 28 and 29, suggesting social capital could be performing fairly even in the most remote wards of Kairezi (Ward 23) and Hwata (Ward 7), enabling the community to “bounce back” by returning to pre-existing conditions. This confirms the sentiments of interviewees that social capital is abundant and innovative in Muzarabani. They mentioned two social schemes: the *Zunde raMambo*, an informal safety net that assists food-insecure households with proceeds from collective land, and the *nhimbe*, a form of collective work assisting households without draught power and other farming equipment.

TABLE 7 Description of the benchmarks of the disaster resilience scores of Muzarabani

Category	DRI score	Description
High	2.149451 to 4.994920	The community has a relatively high potential to “bounce back better” and move forward after disasters. Its capitals have the potential to sustain the basic needs of the community. The community is able to deal with future shocks and stresses.
Fair	0.969961 to 2.149450	The community has a moderate level of resilience to disasters. Certain aspect(s) of capitals have a fair potential to deal with disasters. In the event of disasters, the community can simply “bounce back” by returning to pre-existing conditions. This means that the structures that caused the disaster in the first place are maintained
Low	-0.368159 to 0.969960	The community exhibits very simple resilience that is inadequate to cope with disasters. The community system can push itself back to the low-level equilibria where it may recover but becomes worse than before
Very low	-1.296019 to 0.368160	There is very limited access to capitals leading to higher levels of resilience stress. The critical threshold in asset holdings is presenting tipping points towards reduced resilience. At this level, there is urgent need to build capacities of the community as it is in transient collapse
Absent	-1.888820 to -1.296020	The community shows resilience stress. Community assets are depleted, very low or ineffective to the extent that the community is descending into permanent dysfunction with significant levels of vulnerability. The community needs large investments to push it up into the resilience ladder. The community has high potential of locking itself into poverty traps

Source: Author

TABLE 8 The top 10 wards with the least resilience scores in Muzarabani

Rank	Ward name	Ward no.	Upper/Lower Muzarabani	DRI score	Description of DRI
1	Kairezi	23	Lower	-1.88882	Absent
2	Chiwenga	24	Lower	-1.88882	Absent
3	Utete	19	Lower	-1.88882	Absent
4	Hoya	17	Lower	-1.88882	Absent
5	Kapembere	5	Lower	-1.88882	Absent
6	Gutsa	6	Lower	-1.72418	Absent
7	Chiwashira	9	Upper	-1.51554	Absent
8	Mutemakangu	18	Lower	-1.48739	Absent
9	Maungaunga	2	Lower	-1.35450	Absent
10	Museredza	27	Lower	-1.29602	Absent

Source: Author

TABLE 9 The top 10 wards with high resilience scores in Muzarabani

Rank	Ward name	Ward no.	Upper/Lower Muzarabani	DRI score	Description of DRI
1	Chiweshe	10	Upper	4.99492	High
2	Gatu	15	Upper	3.90373	High
3	Botambudzi	12	Upper	2.14945	Fair
4	Chidikamedzi	28	Upper	1.96038	Fair
5	Mutute	26	Upper	1.86707	Fair
6	Mawari	13	Upper	1.62744	Fair
7	Mutuwa	25	Upper	0.96996	Low
8	Nyamanetsa	14	Upper	0.95981	Low
9	Chinyani	11	Upper	0.57959	Low
10	Palms	29	Upper	0.38790	Low

Source: Author

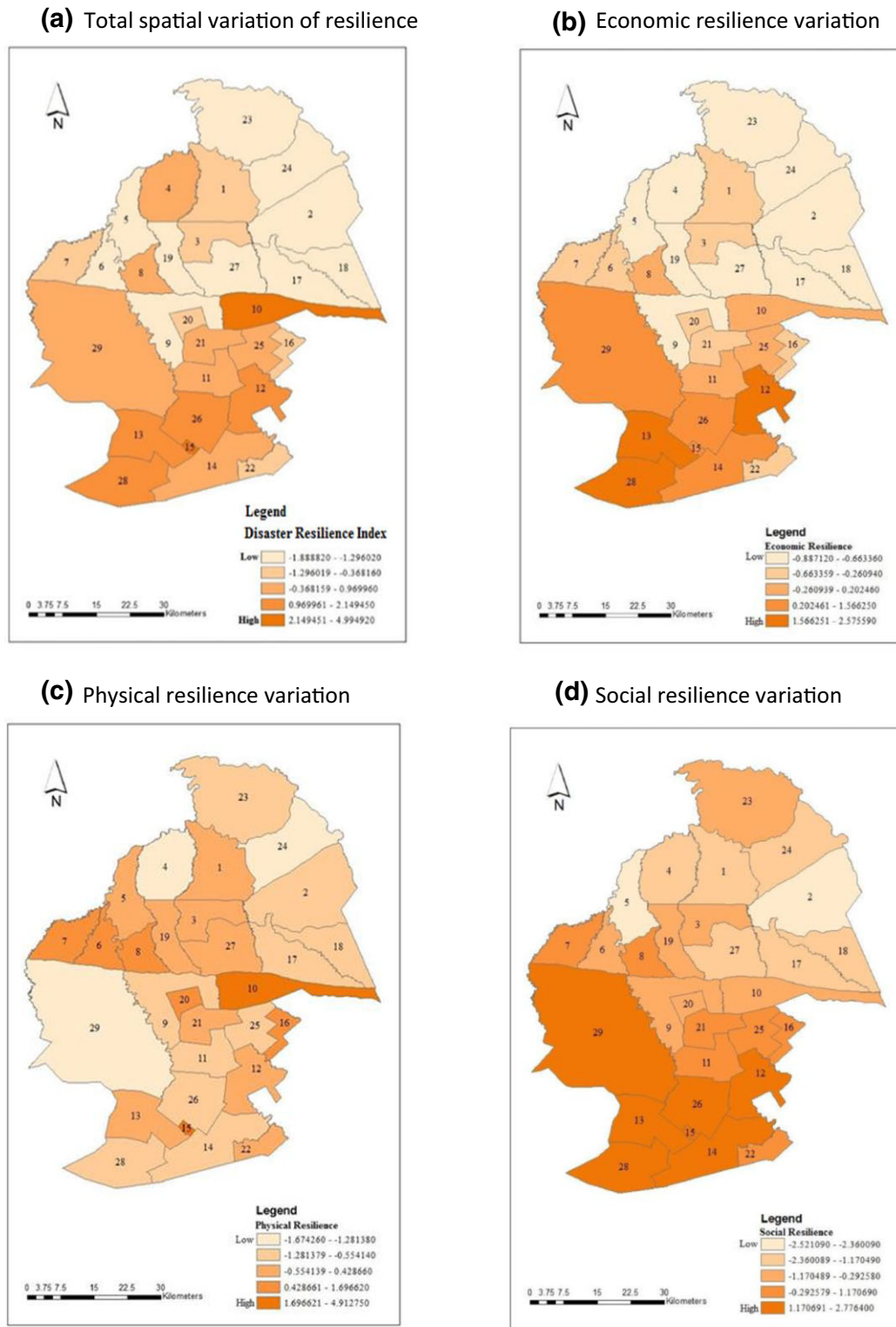


FIGURE 3 (a) Total spatial variation of resilience; (b) economic resilience variation; (c) physical resilience variation; (d) social resilience variation.

4 | DISCUSSION

Place-specific factors are critical to understanding resilience. According to Frazier et al. (2013, p. 102) place-specific factors are “imperative for accurate baseline resilience assessment; without knowledge of pertinent factors, it is impossible to

determine what actions could be implemented to help enhance resilience.” This is particularly appropriate in rural areas where rain-fed farming, high unemployment and low education levels increase the vulnerability to disasters. The place-specific resilience variables for Muzarabani differed slightly from those suggested by Cutter et al. (2008), as some of these variables were broad. This study expanded the broad variables to include the number of people who attained secondary level education as a measure of education attainment; number of households with at least five members as a measure of household labour; traditional dwellings as housing quality; and access to electricity, safe drinking water and proper sanitation as conditions of the built environment. While some of these variables were excluded in resilience models proposed by Cutter et al. (2008, 2010) (most likely due to their widespread availability at the household level in the USA), there were great disparities in access to resources in Muzarabani.

This study expanded Cutter et al. (2003)'s PCA methodology on social vulnerability to resilience analysis. Modelling community resilience showed that the majority of wards (23 out of 29) had low to below low level of resilience, while four were fairly resilient and only two (Wards 10 and 15) had a high resilience potential. As stated earlier, while Ward 10's high resilience score might be attributed to a high number of hospital beds and the low ratio of physicians to patients, the high resilience score in Ward 15 might be explained by being the only peri-urban ward in Muzarabani. The high percentages of households that are not living in traditional dwellings, have access to safe drinking water, proper sanitation and electricity, and have a high number of hospital beds per 10,000 people in Ward 15 may account for its high resilience index.

Some scholars view resilience as the opposite of vulnerability (Lei et al., 2014). The observations in Ward 15 may support the argument, as many rural residents may be vulnerable to disasters due to poor living conditions (Mavhura et al., 2017). However, this is not always the case with agrarian communities. Although the conditions of Ward 10 reflect those of a rural district, with poor living conditions, a high resilience score suggests that some contextual variables such as low physician-patient ratio and the relatively high number of hospital beds exerted great influence to improve the overall resilience score of the ward. The case of Ward 10 demonstrates the limitations of quantitative modelling where one variable or two may skew the overall results, and mask other variables. Modelling various sub-components of resilience in order to understand the performance of each category becomes an important consideration in spatial quantification of resilience. Because this study only modelled the economic, physical and social resilience due to limited data availability, it is clear that qualitative analysis is required to complement quantitative data so as to have full knowledge of the resilience realities.

The use of metrics to model the disaster resilience showed a spatial variation across Muzarabani's 29 wards. This study employed elements of the DROP and CBF to model the spatial variation of resilience in Muzarabani. The selection of economic, social and physical variables was not only based on how well they aligned with those proposed in the literature; they also reflected the context of Muzarabani and the availability of data. The three resilience sub-components were determined by the variables used during the analysis.

It is important to consider the contribution of each sub-component to the overall resilience of Muzarabani. Cutter et al. (2010) found that counties with the highest resilience scores were generally high in all subcomponent scores, while those with the lowest resilience scores were also low in all subcomponent scores. This was not always the case in Muzarabani. For example, Ward 10 scored the highest overall disaster resilience, yet it was not the highest in economic and social resilience scores. Given that Ward 10 is as poor in many respects as any other ward in Muzarabani, this case suggests that some contextual variables may have exerted great influence to improve the overall resilience score of the ward. In this case, the high overall resilience score may be partly attributed to the availability of high numbers of hospital beds and physicians per 10,000 people.

Siebeneck et al. (2015) assert that as a community's access to economic resources increases, the capacity to recover also increases and the disruption of economic systems at the community level decreases. The economic resilience in Muzarabani is stressed possibly due to over-reliance on rain-fed smallholder farming. The limited non-farm activities result in an economy that is not robust to deliver critical goods and services. Given that rain-fed farming is precarious in Muzarabani due to high rainfall variability, frequent droughts and floods, this weakens the economy, which also affects other sub-components of resilience. The high unemployment rate, limited savings to invest in disaster mitigation and the general decline in markets for cash and food crops has reduced community resilience to disasters. Diversification of livelihoods, which include off-farm and non-farm activities, is required in Muzarabani to enhance the ability for communities to deepen and broaden asset holdings (Cramb et al., 2004). This allows a broader range of activities to be pursued as well as providing scope for substitutions between asset categories, such as selling livestock in order to buy farming implements and tools, or using non-farm income to hire seasonal farm labour or other cash inputs.

The physical system in Muzarabani shows low levels of resilience. Critical infrastructure including houses, roads, schools, boreholes and clinics are destroyed by floods. This weakens the community's social, economic and human systems. For example, when children fail to go to schools during flooding, human capital development is deprived. At the same time,

trading on the markets becomes a problem when roads and bridges are destroyed by floods. This contradicts the positive links between rural infrastructure and agricultural growth which enhance the resilience of farmers to hazards, as found by Hanjra et al. (2009) in sub-Saharan Africa. Muzarabani community's ability to absorb and recover from disaster impacts is related to the material resources available to meet the needs of the community during and after disasters. The community response assets including houses and boreholes are either damaged or destroyed by floods. The poor quality of housing, water and sanitation services is manifest in frequent illness, malnutrition and overall discomfort that lower earning potential among adults and adversely affect children's ability to learn (Sekovski et al., 2012). As already stated, the situation is compounded by insufficient economic resources to enable households to recover quickly from the devastating effects of disasters.

5 | CONCLUSION

Community resilience to disasters varies across impacted areas. Resilience is contextual and only indicators that are specific to the context can improve its understanding at local levels. Unlike the generic determinants of resilience, place-based indicators are best selected by the affected community through participatory approaches. They can provide a more accurate estimation of baseline resilience, which enables the community to precisely measure its progress in resilience enhancement (through appropriate mitigation and adaptation initiatives). Generic indicators can mask some of the place-based variables of resilience in affected communities. This research has offered a methodological approach for resilience index construction that accounts for the selection of robust and place-based variables, standardisation, aggregation, and the reduction of uncertainties as they pertain to the internal consistency of data selections. The use of the qualitative methods to select robust and place-based variables for the DRI is a milestone contribution to knowledge. The development of such variables will initiate research interest in the development of metrics that account for all subcomponents of resilience, including natural, economic, social, human and environmental spheres. Using proxy indicators from census reports can inform both policy-makers and disaster practitioners of areas that need priority in terms of resilience building and resource allocation. From a methodological perspective we view this study as being complementary to qualitative studies. Quantifying and visualising resilience provide possible explanations and actions required for decision-makers to address the resilience gaps and disaster risk reduction broadly. However, resilience measurement is complex and may never end. Not only is this complexity due to the multiplicity of conceptualisation but it may be due to the dynamic variables of resilience that change in response to both endogenous and exogenous factors. For resilience assessments to successfully benefit at risk communities, as both an early warning and early action tool, and a tool for informing capacity development, regular updates of the tool might require a predictable mobilisation of resources. As such, the DRI of this study needs to be validated with new census data when they become available. Another opportunity for this research is to consider the impact of weighting on the results of the resilience metrics.

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